COMBINING BOTTOM-UP AND TOP-DOWN APPROACHES FOR UNCERTAINTY QUANTIFICATION

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Physical systems and their environments are random, and mathematical models of systems can be expressed in a nondeterministic framework. For the sake of system characterization, model validation, and other purposes, it is desirable to quantify all aspects of uncertainty in actual system measurements and their mathematical models. Measurements of actual systems yield random outputs because transducers are noisy, and because real systems are nondeterministic. This randomness arises from unit-to-unit variation (when a system consists of an ensemble of structures), random boundary and initial conditions, and random material properties and geometries. Mathematical models can reflect system randomness by expressing system parameters as random variables or random processes. However, the accuracy of a system model is always uncertain, to some degree.

This presentation offers a rationale for combining the bottom-up approach of propagating parametric uncertainty through a model to assess its predictive accuracy, with a top-down approach based on a statistical analysis of the differences between model predictions and experimental measurements for the purpose of uncertainty quantification (UQ), including model UQ. In the top-down approach, differences between corresponding analysis-test pairs are compared in terms of normalized metrics that can be averaged over generically similar conditions to perform system UQ. The bottom up approach uses fundamental experimental results to characterize randomness in mathematical model parameters, and then uses the form of the mathematical model to propagate parametric randomness into system output randomness. One means to compare and combine the two approaches is to select an intermediate set of uncertainty quantification (UQ) metrics and use them to establish the uncertainty accounted for at each step of the analysis process. The purpose of combining the two approaches is to take advantage of the strengths of each approach.

This presentation specifies techniques for comparing and combining the two approaches. It discusses how the results can be used for system UQ and mathematical model validation. The results of some combined numerical and experimental examples are presented to demonstrate the use of the techniques.